

Transit Proximity and Car Parking Demand at Medium/High Density Residential Developments

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Abstract

Theory suggests that the demand for private vehicle travel is inversely proportional to the utility of the alternative modes available and by extension, the demand for car parking is directly related to the demand for private vehicle travel. Because transit utility is enhanced by proximity to major public transport nodes (ie bus and rail stations), the opportunity exists to better match parking supply to demand, based on proximity to major public transport nodes. Doing so yields wider benefits to the community in terms of reducing automobile dependency, traffic congestion, urban sprawl and development costs, while at the same time improving active transport, the viability of public transport and liveability in urban spaces.

This study examines the relationship between car parking demand and proximity to major public transport nodes, using a sample of medium/high density residential developments in Brisbane, Queensland. Qualitative data was gathered by interviewing a number of local property developers and industry bodies. There is evidence from these interviews that the unique characteristics of a development in conjunction with its proximity to major public transport nodes provide opportunities to reduce the amount of car parking supplied.

Quantitative data was obtained from the Australian Bureau of Statistics (ABS) for a sample of 150 Census Collector Districts (CCD) in Brisbane, close to major public transport nodes. Car parking demand was regressed against a range of independent variables, including distance to transit, land use diversity, population density and a range of socio-economic parameters. We found that distance to transit has a significant effect on residential car parking demand. This effect was found to be strongest when residential development was within 1,500 metres of a major public transport node, with the most significant effect evident for developments situated within 400 metres.

The result of this research has the potential to deliver more sustainable and more affordable land use and transport solutions for major urban areas.

1 Introduction

1.1 Background

Council guidelines for car parking provisions in residential developments vary widely, and are often questioned. The supply of car parking is of concern to developers, authorities and residents because it influences the liveability and sustainability of a region. The economic, environmental and social performance, or the triple bottom line performance of a city, may potentially be compromised by inadequate car parking supply at residential developments.

In many large cities, private vehicle mode share is supplemented with alternative modes such as public and active transport. As the public transport system develops, offering higher levels of service, connectivity, comfort, safety and convenience, it becomes a more attractive option. It is therefore plausible that in response, private vehicle mode share will decline, reducing vehicle ownership levels and parking demand at residential developments.

1.2 Aim

This paper presents the results of a study into the relationship between off-street parking demand at medium/high density residential developments and proximity to major public transport nodes. This paper considers the influence of land-use mix and population density. Low density developments were not considered since residents of medium/high density developments tend to have a higher than average public transport mode share.

1.3 Project Scope

Quantitative data was obtained for medium/high density residential developments, as defined by the ABS (2002):

- medium density: semi-detached row or terrace houses and townhouses (refer Figure 1)
- high density: flats, units or apartments (refer Figure 2)

The detailed analysis focussed on a sample of CCD from the 2006 ABS Census, which was the most current available at the time. However, for the purpose of this paper, a brief review of the corresponding 2011 ABS Census data has been undertaken.

Figure 1: Typical Medium Density Residential Dwellings (Coorparoo)



Figure 2: Typical High Density Residential Dwellings (Carindale)



2 Background

The social, environmental and financial impacts associated with car parking supply and demand are extensive.

2.1 Car Parking Supply

Researchers universally acknowledge that parking over-supply is detrimental to natural habitats, contributes to air and water pollution, increases automobile dependency, increases the cost of infrastructure expansion, causes traffic congestion, reduces the liveability of urban spaces and affects the economic viability of developments (McKibbin 2011, Forinash et al 2003, Ison and Rye 2008). The dedication of land to car parking reduces green space and minimises the amount of space available for higher uses.

As automobile dependency increases, the cost of providing parking to urban areas increases, inflating the cost of brownfield or infill developments (Forinash et al 2003). Forinash et al 2003, and Shoup 1997 contend that the supply of parking subsidises personal automobile use and encourages automobile use in areas where convenient transportation choices exist. In Brisbane, minimising urban sprawl and automobile dependency are key aims of the Local and State Government, as articulated in their respective transport strategies for the region (Brisbane City Council 2008, Queensland Transport 2001). These strategies aim to maximise non-car mode shares by increasing the attractiveness and convenience of walking, cycling and public transport.

Forinash et al 2003 and McKibbin 2011 suggest increasing public transit use, and encouraging the use of active transport or shared parking schemes as ways of reducing car parking demand. This could be achieved by situating infill development closer to major public transport nodes, perhaps even providing financial incentives for developers to do so. This approach has led to the notion of promoting context-sensitive car parking regulations, particularly in relation to residential high density developments (Forinash et al 2003, Engel-Yan and Passmore 2010, Cuddy 2007).

2.2 Car Parking Demand

Rowe, Bae and Qing 2010 analysed the affect of local context-sensitive data on car parking demand of multi-family apartment buildings in Seattle. Their work considered a range of factors including transit frequency, proximity to transit, transit travel time, transit reliability and parking demand. They study found that high levels of transit service provide a viable alternative to vehicle ownership. The study also found that parking demand was significantly lower than the amount of car parking supplied.

McKibbin 2011 undertook a similar study, but also considered the influence of local land uses. This study analysed the effect of several built environment factors on mode share in Sydney. The study closely mimics Cervero and Kockelman 1997, as well as the meta-analysis by Ewing and Cervero 2010. The independent variables used were density, diversity, distance to transit, destination accessibility and pedestrian orientated design. Three control variables were also used to isolate the effect of the built environment factors on mode share (ie weekly income, car ownership and percentage of work trips to CBD). The study measured the elasticity of each built environment variable with respect to mode share and concluded that density, land use diversity, distance to transit and destination accessibility were all important factors. McKibbin 2011 also concluded that the impact of distance to transit on mode share was weak, and that the destination accessibility was more important.

On distance to transit, Ewing and Cervero 2010 found that research studies were not directly comparable since there was a small sample size of only three studies that considered this variable and the results of these studies were highly variable. McKibbin 2011, and Ewing and Cervero 2010 acknowledge that further research into the impact of distance to transit on transportation and travel behaviours was required.

2.2.1 Distance to Transit

There is some evidence in the literature to suggest that proximity to local transit is related to parking demand. Schimek 1996 found that vehicle ownership per household is reduced within three blocks of a major transit station. In Montgomery County, Maryland, USA for example, minimum parking requirements are granted a 20% reduction, depending on the distance of the development from a Metrorail station (Forinash et al 2003). In Los Angeles, California, a reduction to minimum car parking requirements for affordable housing units is granted for sites that are within approximately 460 meters of mass transit or a major bus line (Engel-Yan and Passmore 2010).

2.2.2 Density

The literature on travel demand consistently acknowledges density as an important determinant of transport use. Newman and Kenworthy 1989 conducted a seminal study into the use of public transport and petrol consumption, focussing particularly on the variability of density. They noted that the effect of density on transport use was most pronounced in world cities where population density was greater than 30 people per hectare.

Schimek 1996 found that local density was important, and that households situated in high density areas tended to travel less by private vehicles.

Forinash et al 2003 stated that the most important factor in relation to travel and residential developments is density. Forinash et al 2003 found that in three American cities, “each time

residential density doubles, auto ownership falls by 32 to 40 percent”. The explanation of this phenomena was that higher urban densities translates to destinations that are closer together, and hence easier to reach on foot and by bicycle, reducing the need to own a car.

Mees 2009 examined the relationship between metropolitan density and mode share, to conclude that in association with other socio-economic factors, density does affect travel behaviour when “all other factors are equal”.

In a study on mode share in Australian cities Rickwood and Glazebrook 2009 found that local population density was a minor determinant of public transport use. In fact density was highly correlated with several other variables (car ownership, local employment and transport accessibility) thereby serving as a proxy for these variables.

2.2.3 Diversity

Another important built environment factor that has been shown to impact on the transportation characteristics of a city or suburb is diversity, which reflects the mix of activities available in an area. Cuddy 2007, and Cervero 1996 found that the extent of land use diversity surrounding a residential development site is highly correlated with vehicle ownership at that site.

Recently, Ewing and Cervero 2010 measured the diversity of an area as a jobs-to-housing ratio or jobs-to-population ratio. In a study by Leck 2006, land use mix in conjunction with residential density and employment density was found to be inversely related to vehicle miles travelled. This contradicts the findings of McKibbin 2011, who concluded that a jobs-housing diversity index was unrelated to non-car mode share in Sydney.

3 Approach

3.1 Overview

The data analysis aspect of the study was conducted in two distinct stages. The first stage gathered qualitative data from a sample of local property developers and their industry body. The second stage involved the collection of quantitative data to test for a relationship between car parking demand at medium/high density residential developments and proximity to major public transport nodes. The output from these two stages was then compared to identify any consistent findings.

3.2 Qualitative Analysis

The first stage of data collection involved interviewing local property developers as well as their industry association with a view to gaining an understanding of the issues associated with the provision of car parking in medium/high density residential developments. This phase of the research captured qualitative information regarding the relationship between distance to transit and car parking demand that may not have been evident in a statistical analysis (see below). Furthermore, the interviews provided an opportunity to verify the experience of local property developers with that reported by Forinash et al 2003, McKibbin 2011, and Ison and Rye 2008.

Each interviewee was provided with a standard list of ten questions, with the interviews lasting about 30 minutes. Respondents were asked to give their perspective on the significance of a development’s proximity to major transport centres, as well as their opinion of the current Council guidelines on the provision of car parking supply.

3.3 Quantitative Analysis

During this phase of the work, a multiple regression analysis was conducted on a range of variables known to influence car parking demand, with a view to quantifying the significance of distance to transit.

3.3.1 Analysis Variables

Table 1 describes the variables used in the analysis and their source. The independent variables were selected based on the literature. Most of the variables were sourced from ABS 2006 Census data.

Table 1: Analysis Variables and Data Sources

Variable	Unit of Measurement	Source
Dependent Variable		
Demand	Average number of motor vehicles parked at medium and high density residential dwellings	ABS Census
Independent Variables		
Distance	Straight line distance between CCD centroid and major public transport node	GIS maps
Diversity	Number of jobs by industry at SLA level, using Simpson's Index where 1=diverse and 0=homogeneous	ABS Census
Density	Persons per hectare at CCD level	ABS Census
Control Variables		
Income	Average weekly income at CCD level	ABS Census
Bedrooms	Average number of bedrooms in medium and high density residential developments at CCD level	ABS Census
Gender	Percentage of females at CCD level	ABS Census
Age	Average age of persons at CCD level	ABS Census

The number of motor vehicles per dwelling obtained from the 2006 ABS Census Data was used as a proxy for automobile ownership. The motor vehicles per dwelling census count included all automobiles owned or used by each dwelling, and excluded motorbikes and scooters.

Distance to transit was calculated using MapInfo GIS software, based on the straight-line distance between the centroid of the CCD and each major public transport node. This simplifying assumption implies that all of the medium/high density residential dwellings are situated at the CCD centroid, when in reality they would be scattered throughout the CCD.

Land use diversity was measured using an index based on the number of jobs in eight different industry sectors that support residential areas, namely:

- retail trade
- accommodation and food services
- financial and insurance
- education and training
- healthcare and social assistance
- arts and recreation services
- other personal services
- public administration and safety services

In order to measure the richness and evenness of the spectrum of industries represented in each region, a variant of Simpson's Diversity Index (Barcelona Field Studies Centre 2011) was employed as follows

$$D = \left[\frac{S}{(S-1)} \left[1 - \sum \left(\frac{n}{N} \right)^2 \right] \right]^2 \quad (\text{Equation 1})$$

Where: D = Diversity Index (1 = most diverse and 0 = least diverse)
n = number of jobs in each industry sector within the area
N = total number of jobs for all industries within the area
S = number industry sectors considered within the area

Areas in which the number of jobs is equally spread amongst the eight different industries generate a diversity index value of one, whereas areas that have industries which are significantly over/under represented in employment have a value close to zero. For example, application of Equation 1 to the suburb of Carindale yields a diversity index of 0.54 (the lowest and least diverse in the sample), compared to 0.93 for Coorparoo (the highest and the most diverse in the sample).

A series of control variables were also included in the research in order to account for local demographic and socio-economic effects. The inclusion of the control variables was necessary in order to assess the strength of the significance of the three independent variables on car parking demand (Frank and Pivo 1994).

3.3.2 Data Collection

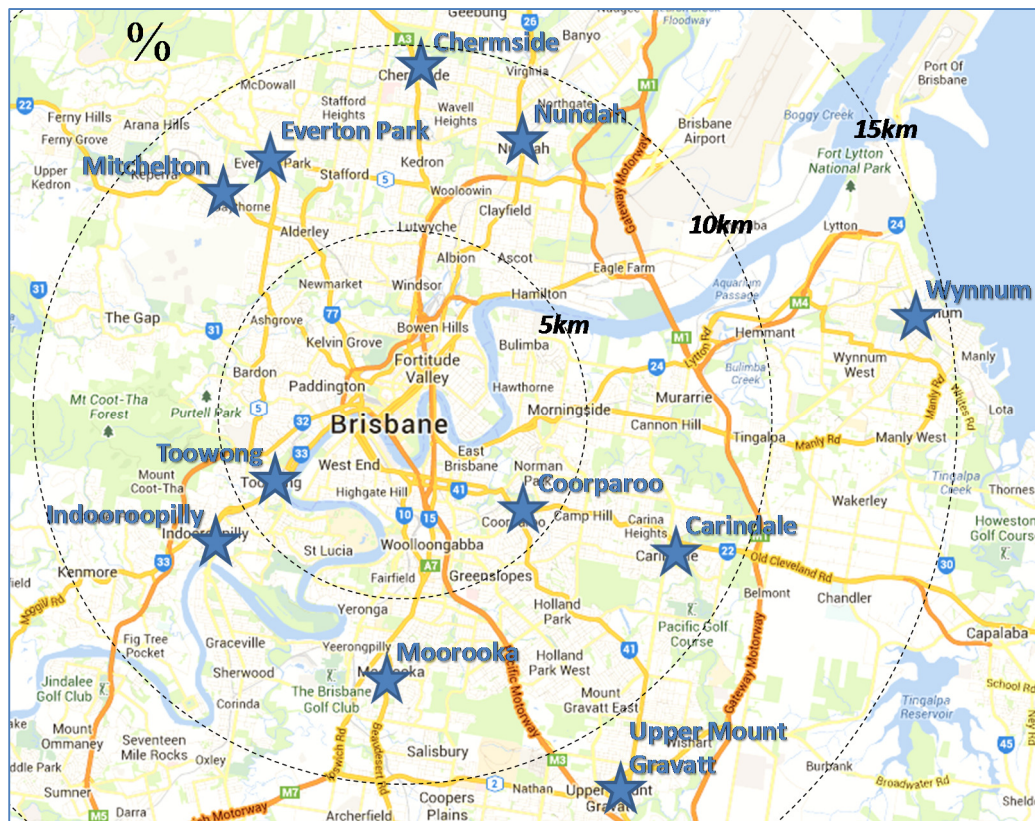
A sample of 11 major public transport nodes around Brisbane was selected for the purpose of our study. These aligned with the major transportation centres identified in the Transport Plan for Brisbane (Brisbane City Council 2008) and the Brisbane City Plan (Brisbane City Council 2000) and included:

- Chermside
- Mitchelton
- Toowong
- Indooroopilly
- Upper Mount Gravatt
- Carindale
- Wynnum
- Nundah
- Moorooka
- Coorparoo
- Everton Park

The geographic spread of the ten major public transport nodes selected is shown in Figure 1. As shown, they are located on both sides of the river and at varying distances from the CBD.

The independent and socio-economic control variables were calculated for 150 CCD adjacent to the major public transport nodes shown in Figure 1. Any CCD that did not contain medium/high density residential developments was excluded from the study.

Figure 1: Map of Major Transport Nodes Sampled



It was observed that medium/high density residential developments were uncommon in CCD located at distances greater than approximately 1,500 metres from the designated transport nodes. Five control areas, for CCD located at a distance greater than 1,500 metres from a major public transport node, were included.

Data were entered into an Excel spreadsheet, and exported into Minitab for statistical analysis. At this stage, any outliers were identified and excluded, resulting in a final sample of 140 CCD (including five control CCD).

3.3.3 Data Analysis

Initially, scatterplots of the input variables were prepared to identify any obvious trends. Following this, a multivariate analysis was undertaken in Minitab to quantify the significance of these trends, using a t-test. Finally, a series of multiple linear regression models were developed to assess the combined impact of all of the variables. The significance of the regression models was assessed using standard F and R² statistics.

3.4 Assumptions and Limitations

The analysis presented in this research project assumed that the public transport system was fully developed. However, the public transport system in Brisbane has been significantly improved and augmented since 2006, due to the construction of new busways and the introduction of new services. Accordingly, more recent evidence of a consequent decrease in automobile dependency and hence car parking demand may be more apparent in the 2011 Census data.

The ABS Census data is aggregated for all developments within a particular CCD, making it particularly difficult to ascertaining the precise distance between each medium/high density residential development in nearby major public transport node. This is because the precise location of the residential dwellings in the CCD was unknown. The amalgamated socio-economic data also failed to accurately describe the characteristics of the residents of the medium/high density dwellings located within each CCD.

Our study does not control for attitudinal variables, which according to Schimek (1996) and Kahn and Morris (2009), can influence car ownership levels. For example, some households may choose to live 'green' and go without a car because of their environmental philosophy, irrespective of their proximity to major public transport nodes.

There was also a six year time lag between the ABS Census conducted in 2006 and the interviews carried out in 2012. Any significant changes in the local transport infrastructure, transport service provision and technological advances occurring in the intervening years could potentially undermine the strength of any comparisons drawn between the two years.

4 Results and Findings

4.1 Stakeholder Feedback

The interviews were distributed to eight local property developers and two industry advisory groups. Of these, four developers and one advisory body participated in the interviews. The response rate of 50% provides adequate information to allow us to draw broad conclusions regarding the primary variable of interest (ie distance to transit). The interviews were conducted by telephone and in person, with all responses treated in confidence.

Several respondents were very conscious of the costs of parking over-supply or under-supply. If over-supply of parking was an issue at inner city developments, then the excess car spaces could be sold for a small profit. Respondents deemed the problem of under-supply of car parking as critical, because car parking under-supply hinders the sale of residential apartments.

Respondents generally agreed that developments within walking distance of public transport nodes could require less car parking. On average, respondents indicated that a lower than average parking supply would suffice for medium/high density residential developments within 425 metres of a major public transport node. However, respondents noted that other factors also influence residential parking demand, including:

- end of trip facilities
- accessibility to major activities centres, other than the CBD
- connectivity of the public transport system
- climate

All respondents listed the requirements of the target market as the primary factor that typically governs the amount of car parking supplied in a development.

Respondents were of the opinion that the Brisbane City Council guidelines need to be more flexible with respect to the provision of residential parking. The consensus was that car parking supply should follow demand, as dictated by market conditions. One respondent noted that

the Council guidelines encouraged smaller unit sizes, which in turn require less car parking. At least four out of five respondents were able to identify at least one instance in which car parking was provided at a rate less than the regulated Council minimum. However, in each case the subject site was within walking distance of a railway station or bus station.

Examples were given where proximity to transit, in conjunction with other factors, may reduce the level of car parking supplied to medium and high density residential developments.

Respondents also noted the following financial issues associated with the provision of off-street parking in residential developments:

- off-street car parking can be costly to provide and the design of residential buildings may be determined by the car parking layout, in order to reduce the overall development cost
- basement car parking is extremely expensive
- ground level parking is undesirable due to the opportunity cost associated with a higher order use (eg retail) for ground floor space
- podium parking is relatively cheaper, although is often not perceived to be aesthetically pleasing
- normally car parks cannot be sold separately at a profit

Respondents suggested that more efficient car parking ratios could be employed if the following factors were considered:

- the level of service provided by public transport and cycling options
- cultural shift in residents to more public transport and active transport mode shares
- car sharing and unbundling the titled right to car parking spaces

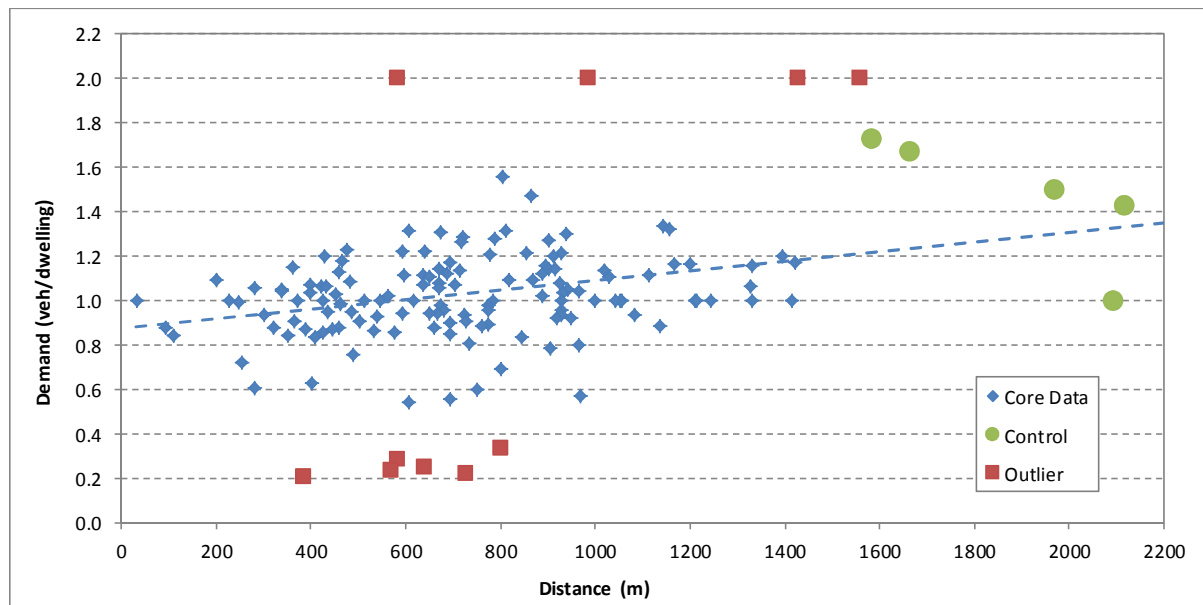
The key points that emerged from the stakeholder interview were:

- The marketability of a residential development project was of paramount importance to all respondents interviewed.
- A reduction in the amount of car parking provided to a residential development was perceived to decrease the marketability of a development, and hence increase the risk that the residential apartments cannot be sold.
- There is evidence to suggest that the individual factors of a project in conjunction with the proximity of a development provide an opportunity to reduce the amount of car parking supply at medium and high density residential developments in Brisbane.
- If a medium or high density residential development is situated within walking distance of a major transport node, it is foreseeable that a reduction to the minimum parking ratios set by council could be employed.

4.2 Statistical Results

An initial plot of parking demand versus distance to transit is shown in Figure 2 for all 150 candidate CCD, including outliers and the five control CCD. It is evident that there is a positive relationship between parking demand and distance to transit. However, the R^2 statistic is relatively low (ie 16.2% excluding outliers), which indicates that more variables are required to fully explain the observed variation in car parking demand. The outliers are highlighted and these were excluded from the subsequent analyses.

Figure 2: Demand versus Distance



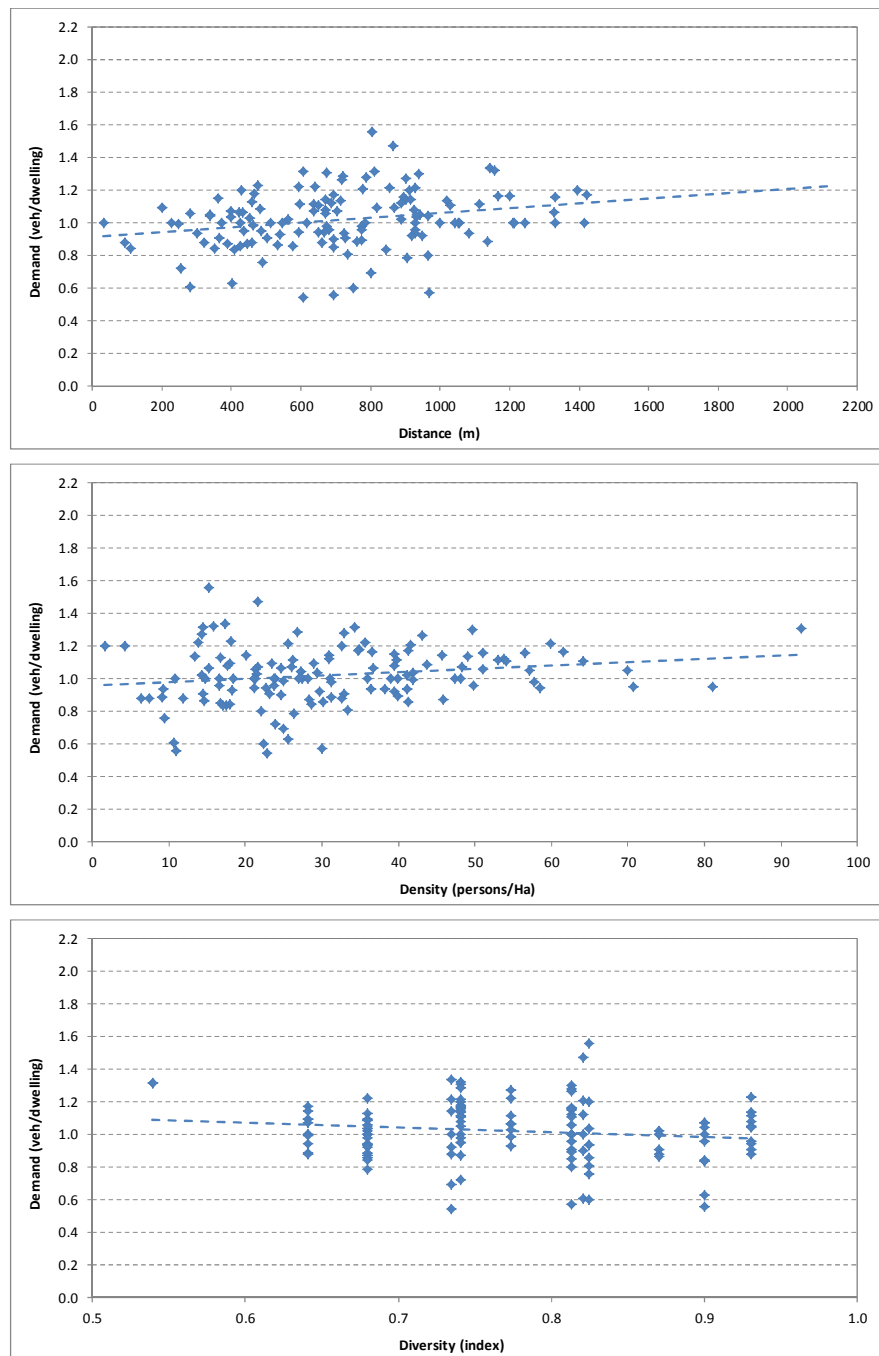
The five control CCD are also highlighted in Figure 2, although no obvious trend is discernible. These CCD were also excluded from the subsequent analyses.

4.2.1 Scatterplots

The scatterplots of car parking demand versus distance to transit, population density and land use diversity are shown in Figure 3. Based on these plots, it appears that there is:

- a positive relationship between car parking demand and distance, which means that as distance to transit increases, car parking demand increases
- a positive relationship between car parking demand and density, which means that as the population density increases, car parking demand increases – this result appears to contradict the findings of McKibbin 2011, and Ewing and Cervero 2010, although their measure of density incorporated both population and jobs
- a negative relationship between car parking demand and diversity, which means that as the mix of local land uses increases, car parking demand decreases

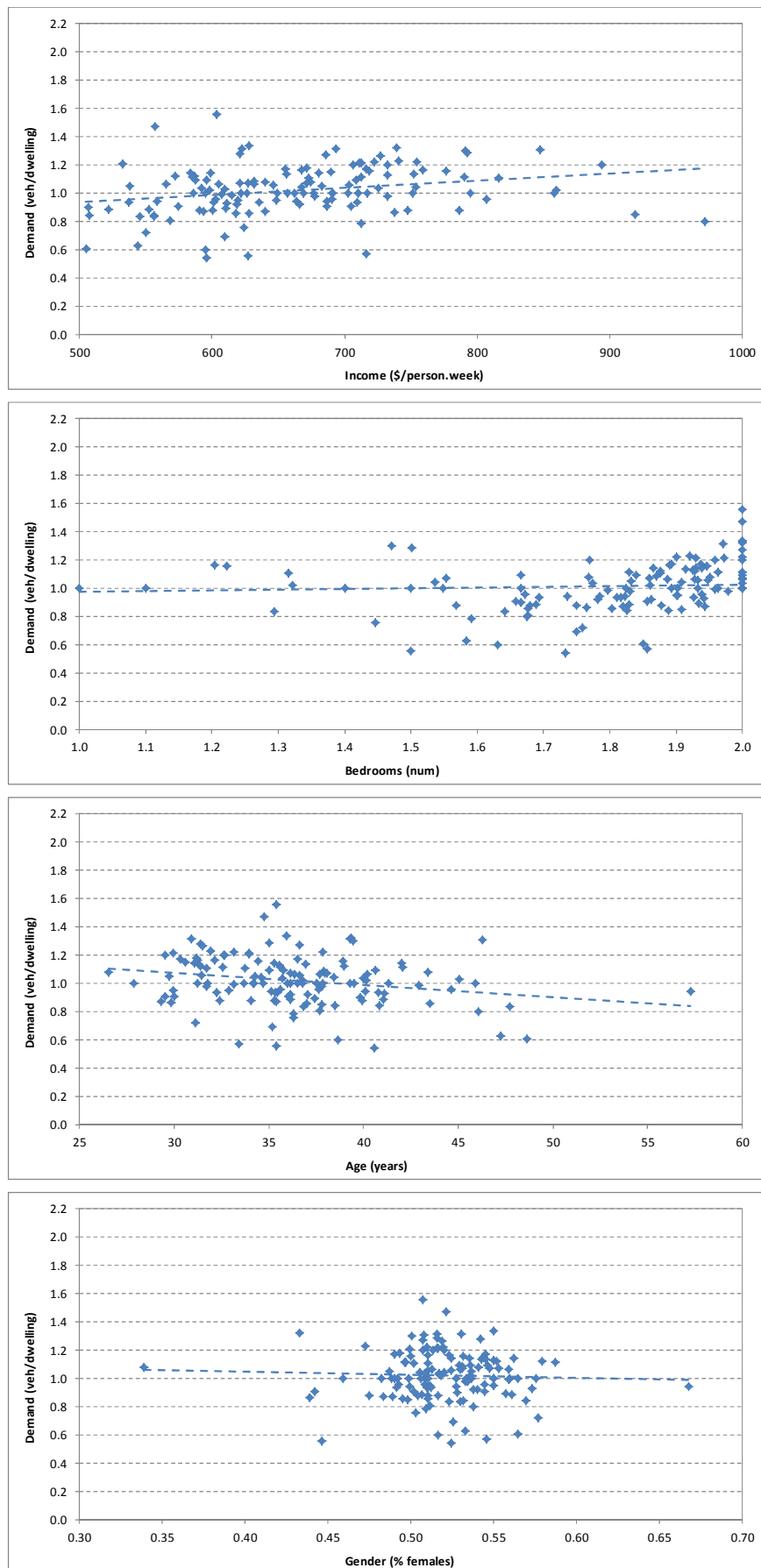
Figure 3: Scatterplots of Demand versus Independent Variables



The scatterplots of car parking demand versus the socio-economic variables are shown in Figure 4. Based on these plots, it appears that there is:

- a positive relationship between car parking demand and income
- no obvious relationship between car parking demand and the number of bedrooms
- a negative relationship between car parking demand and age
- a weak negative relationship between car parking demand and percentage of females

Figure 4: Scatterplots of Demand versus Socio-Economic Variables



4.2.2 Regression Models

Several multiple regression models, each containing the variable distance, were analysed. All of the models regressed distance on parking demand. Table 2 summarises the results of the regression analysis.

Table 2: Regression Models

Model		R ²	Distance p-val
1	Demand = 0.161 + 0.00009425 Distance + 0.000693 Density - 0.128 Diversity + 0.000584 Income + 0.108 Bedrooms - 0.00751 Age + 1.078 Gender	0.342	0.009
2	Demand = -0.044 + 0.000287 Distance + 0.00307 Density - 0.018 Diversity + 0.373 Bedrooms	0.412	0.000
3	Demand = 0.0997 + 0.0001 Distance + 0.00204 Density + 0.373 Bedrooms	0.500	0.028
4	Demand = 0.169 + 0.000084 Distance + 0.373 Bedrooms	0.476	0.067

Focussing first on the variable distance to transit, the t-statistics are and corresponding p-values are significant at the 10% level. We can therefore conclude that there is a significant relationship between distance to transit and car parking demand for medium/high density residential developments in close proximity to major public transport nodes. The R² statistic for the regression models range from 34% to 50%, which is comparatively low given the aggregate nature of the input data. Clearly, other variables are required to more fully explain the observed variation in car parking demand.

While the sign for the coefficient for distance and diversity appears logical, the sign for density is counter-intuitive. While the literature suggests it should have a negative coefficient, our models ascribe a positive value. It is not immediately obvious why this should be the case. Perhaps it is because our measure of density differed to that used by others. For example, McKibbin 2011, and Ewing and Cervero 2010, quantified density in terms of population and employment per hectare, where as we only considered population per hectare. Clearly, the manner in which density was quantified and the role of this variable in explaining car parking demand requires further investigation.

4.2.3 2011 Data

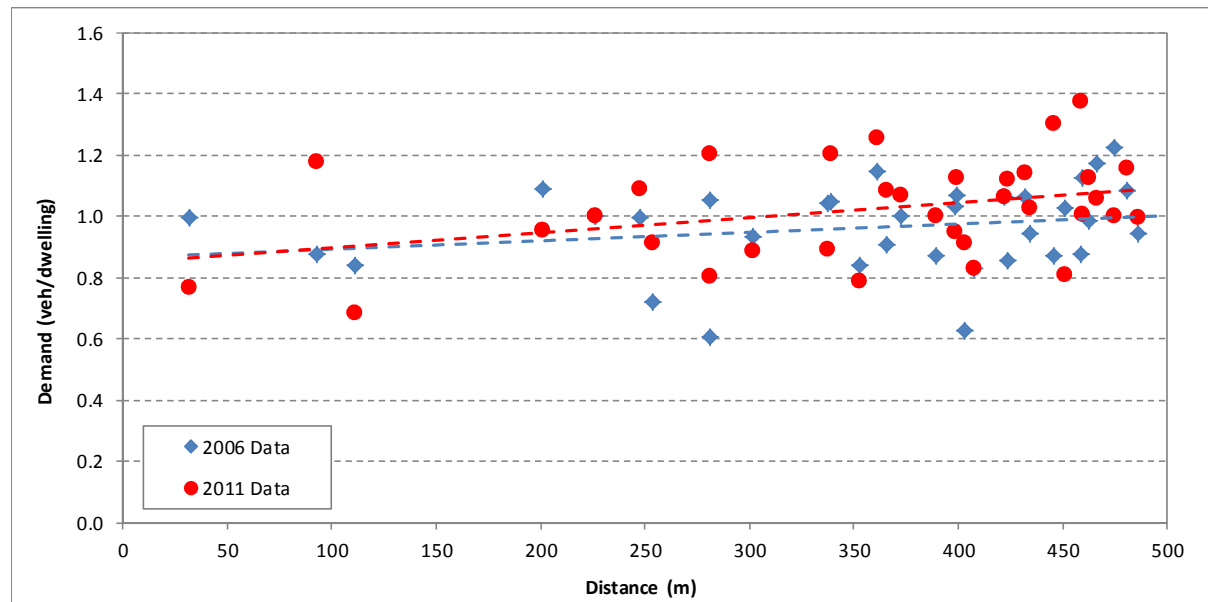
For the purpose of this paper, a brief review of the corresponding 2011 ABS Census data has been undertaken. The scatterplot shown in Figure 5 includes the 2006 and the 2011 ABS Census data for a subset of 34 CCD within 500m of a major public transport node. The key points to note from this comparison are:

- average car ownership levels across these 34 CCD increased by 6.2%, from 0.96 cars/dwelling in 2006 to 1.02 cars/dwelling in 2011

- both data sets demonstrate a positive relationship between parking demand and distance to a major public transport node
- this relationship has strengthened (ie become steeper) with time

This brief comparison of the 2006 and 2011 data for a sub-set of CCD tends to confirm the temporal stability of the study findings.

Figure 5: 2006 and 2011 Demand versus Distance



4.3 Summary

The results of our study indicate that:

- There is a significant relationship between car parking demand and proximity to transport for medium and high density residential developments that are situated within 1,500 metres of a major transport node.
- The proximity of the development to a major transport node has the most significant effect on the provision of car parking spaces where the residential development is located within 400m of the transportation centre.
- The proximity of a major transport node to medium and high density residential developments, in conjunction with other factors such as the marketability of the project, provides developers with the opportunity of supplying less car parking at the development.

5 Conclusions and Recommendations

5.1 Conclusions

This study concluded there is a relationship between car parking demand and distance to transit based on the output of a statistical analysis of 2006 ABS Census data and interviews conducted with Brisbane property developers. However, other parameters in conjunction with distance are required to more fully explain the variation in car parking demand. Furthermore, the measurement of the estimated parameters in this study could be improved, particularly in relation to measuring the distance between individual residential developments, as well as the resident population of each CCD.

The significant relationship between car parking demand and distance to transit identified in this paper should be used to draft more flexible regulations governing the provision of car parking at medium/high density residential developments. In this way, more sustainable and affordable transport and housing solutions can be achieved.

5.2 Recommendations

Several improvements could be implemented in order to more accurately describe and measure the variables in this study, including:

- the distance between a development and the nearest major public transport node could be more accurately obtained by measuring the actual walking/cycling distance via a field survey or aerial photographs
- a more refined measure of diversity could be used based on a more relevant list of industry subsectors and/or by reducing the contributing area from the suburb level down to a smaller area centred on the CCD in question
- the statistical analysis could be updated using the 2011 ABS Census data, which was not available at the time of the work
- additional variables could be included in the regression modelling, such as destination accessibility, transit frequency or distance to employment
- a dummy variable could be included to distinguish between rail stations and bus stations
- the methodology described here could be applied to other major urban areas in Australia to confirm the geographic robustness of the conclusions

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